01-08-02 JC10 Rec'd PCT/PTO 02 JAN 2002

FORM PTO-1390 (REV 5-93) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 10191/2175
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 10/030586

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE(S) CLAIMED
PCT/DE00/02043	(30.06.00) 30 June 2000	(02.07.99) 02 July 1999 (22.10.99) 22 October 1999

TITLE OF INVENTION
FUEL INJECTOR

APPLICANT(S) FOR DO/EO/US

LANDER, Hans; HEINBUCH, Petra; SCHATZ, Frank; GLOCK, Armin; SCHULMEISTER, Ulrich; PILGRAM, Guido; HOFMANN, Thomas; KRAATZ Ullrich; DANTES Guenter; NOWAK Detlef; HEYSE, Joerg; and HACKENBERG, Juergen

Applicant(s) herewith submit to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) (unsigned).
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
    ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☒ A substitute specification and a marked up version thereof.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report, International Preliminary Examination Report and Form PCT/RO/101.

Express Mail No. EL244510201

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U.S. APPLICATION NO. if known, see 37 C.F.R.1.5 10/030586	INTERNATIONAL APPLICATION NO. PCT/DE00/02043	ATTORNEY'S DOCKET NUMBER 10191/2175

17. ☒ The following fees are submitted:

	CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO .... $890.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) ... $710.00 No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) .... $740.00 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... $1,040.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 890	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	10 - 20 =	0	X $18.00	$ 0	
Independent Claims	1 - 3 =	0	X $84.00	$ 0	
Multiple dependent claim(s) (if applicable)			+ $280.00	$ 0	

TOTAL OF ABOVE CALCULATIONS =	$ 890	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).	$	
SUBTOTAL =	$ 890	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +	$	
TOTAL NATIONAL FEE =	$ 890	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +	$	
TOTAL FEES ENCLOSED =	$ 890	
	Amount to be: refunded	$
	charged	$

a. ☐ A check in the amount of $____________________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of $890.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Richard Mayer (By Reg. No. 33,865 Karen S DE0150H)

SIGNATURE

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NAME

1/2/2002
DATE

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[10191/2175]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s)	:	Hans LANDER et al.
Serial No.	:	To Be Assigned
Filed	:	Herewith
For	:	FUEL INJECTOR
Art Unit	:	To Be Assigned
Examiner	:	To Be Assigned

U.S. Patent & Trademark Office
Assistant Commissioner for Patents
P.O. Box 2327
Arlington, VA 22202

PRELIMINARY AMENDMENT AND
37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT

SIR:

Please amend without prejudice the above-identified application before examination, as set forth below.

IN THE SPECIFICATION AND ABSTRACT:

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract, but without claims) accompanies this response. It is respectfully requested that the Substitute Specification (including Abstract) be entered to replace the Specification of record.

IN THE CLAIMS:

Without prejudice, please cancel original claims 1 to 15 and new/substitute claims 1 to 9, and please add new claims 16 to 25 as follows:

--16. (New) A fuel injector for use in projecting directly into a combustion chamber of an internal combustion engine, the fuel injector comprising:

a fuel inlet;

a movable valve-closure member;

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a fixed valve seat to cooperate with the valve-closure member to open and close a valve; and

a downstream valve end including a component and a fuel outlet, wherein:

the fuel outlet includes at least one discharge orifice of the component,

the at least one discharge orifice is arranged downstream of the fixed valve seat,

the component includes a coating around the at least one discharge orifice, including at least in an outlet area of the at least one discharge orifice, and

the coating includes a layer containing fluorine.

17. (New) The fuel injector of claim 16, wherein the layer containing fluorine includes fluorosilicate (FAS).

18. (New) The fuel injector of claim 16, wherein the layer containing fluorine includes a heat-resistant PTFE-similar layer.

19. (New) The fuel injector of claim 16, wherein the internal combustion engine includes an externally supplied ignition.

20. (New) The fuel injector of claim 16, wherein the internal combustion engine includes an auto-ignition.

21. (New) The fuel injector of claim 16, wherein the coating is provided in a ring shape around the at least one discharge orifice on a downstream surface of the component.

22. (New) The fuel injector of claim 16, wherein the coating is provided over an entire surface of a downstream surface of the component.

23. (New) The fuel injector of claim 21, wherein the coating extends into the at least one discharge orifice.

24. (New) The fuel injector of claim 16, wherein the layer containing fluorine is appliable by spraying.

25. (New) The fuel injector of claim 22, wherein the coating extends into the at least one discharge orifice.--.

Remarks

This Preliminary Amendment cancels without prejudice original claims 1 to 15 and new/substitute claims 1 to 9 in the underlying PCT Application No. PCT/DE00/02043, and adds without prejudice new claims 16 to 25. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. In the Marked Up Version, underlining indicates added text and bracketing indicated deleted text. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/DE00/02043 includes an International Search Report, dated November 13, 2000. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment.

The underlying PCT application also includes an International Preliminary Examination Report, dated September 24, 2001, and an annex (including new/substitute claims 1 to 9). An English translation of the International Preliminary Examination Report and the annex accompanies this Preliminary Amendment.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,
KENYON & KENYON

Dated: 1/2/2002

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[10191/2175]

FUEL INJECTOR

FIELD OF THE INVENTION

The present invention relates to a fuel injector.

BACKGROUND INFORMATION

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, particularly with direct injection of gasoline or injection of diesel fuel, a problem may occur; namely, that the downstream tip of the injectors projecting into the combustion chambers may get coked by fuel deposits (that is, soot particles formed in the flame front may deposit on the valve tip). Thus, with injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters (such as, for example, static flow amount, spray dispersal angle, drop size, skeining ability) may exist over the service life of the injectors, which may lead to disturbances in the running of the internal combustion engine and a failure of the injectors.

SUMMARY OF THE INVENTION

An exemplary fuel injector according to the present invention may have the advantage that the negative effects of the coking (soot deposit) on the valve tip projecting into the combustion chamber may be reduced or eliminated. The application of coatings on the downstream valve end, especially around the outlet areas of the discharge orifices, may reduce or prevent coking or formation of covering (soot) on the valve end that may negatively influence the spray parameters and the valve function.

It may be advantageous to apply layers on the valve end, by which either a catalytic conversion (burning) of the deposits may be effected or the surface energy and/or the surface roughness of the component to be coated may be reduced, a change in the wetting properties thereby being achieved, or the formation of a reaction layer thereby being prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows an exemplary fuel injector according to the present invention inserted into a location bore of a cylinder head.

Figure 2 shows a longitudinal cross-section of an exemplary fuel injector according to the present invention.

Figure 3 shows a valve end coated according to an exemplary embodiment of the present invention.

Figure 4 shows another valve end coated according to an exemplary embodiment of the present invention.

Figure 5 shows an alternative guide and seat area on a valve end at the spray-discharge side.

Figure 6 shows a longitudinal cross section of an exemplary fuel injector according to the present invention for an auto-ignition internal combustion engine.

Figure 7 shows an end of the fuel injector of Figure 6 on the combustion chamber side.

DETAILED DESCRIPTION

Figure 1 shows a cut-off segment of a cylinder head 1 of an internal combustion engine, particularly a mixture-compressing internal combustion engine with externally supplied ignition. Formed in cylinder head 1 is a graded location bore 2 that extends symmetrically along a longitudinal axis 4 up to a

combustion chamber 3. A fuel injector 5, according to an exemplary embodiment of the present invention, is inserted into location bore 2 of cylinder head 1. Fuel injector 5 may be used for direct injection of fuel, particularly gasoline, but may also, for example, be used for injection of diesel, as shown in Figures 6 and 7, into combustion chamber 3 of the internal combustion engine. Fuel injector 5 may be actuated electromagnetically via an electrical connecting cable 6. The fuel may be supplied to fuel injector 5 by an intake nipple 7. The fuel injector 5 of Figure 1 is a top-feed injector, in which the fuel is guided in the axial direction from intake nipple 7 through entire injector 5, the fuel being ejected at end 8 on the spray-discharge side, opposite the end on the intake side, into combustion chamber 3.

To protect fuel injector 5 near combustion chamber 3 from overheating, injector 5 may be at least partially surrounded, for example, with a thermal-protection sleeve 9 also inserted in location bore 2, although the thermal-protection sleeve may be dispensed with.

Figure 2 shows a cross-section of an exemplary fuel injector 5 according to the present invention. An electromagnetically operable valve, which has a tubular, largely hollow-cylindrical core 11 that is at least partially surrounded by a magnetic coil 10, is used as the internal pole of a magnetic circuit. For example, a graded plastic coil form 13 receives a winding of magnetic coil 10 and, in conjunction with core 11 and a non-magnetic intermediate part 14 partially surrounded by magnetic coil 10, permits a particularly compact and short injector in the area of magnetic coil 10. Instead of the electromagnetic actuating element, fuel injector 5 may also be actuated in a piezoelectric or magnetostrictive manner.

Provided in core 11 is a traversing longitudinal opening 15, which extends along a longitudinal valve axis that coincides

with the longitudinal axis 4 of the location bore 2 of Figure 1. Core 11 of the magnetic circuit also serves as intake nipple 7. Fixedly joined to core 11 above magnetic coil 10 is an outer metallic (such as, for example, ferritic) housing part 16 which, as an external pole or an outer conductive element, closes the magnetic circuit and completely surrounds magnetic coil 10, at least in the circumferential direction. Provided in the longitudinal opening 15 of core 11 on the intake side is a fuel filter 17 that filters out fuel components that, because of their size, may cause clogging or damage to the injector.

Joined imperviously and fixedly to upper housing part 16 is a lower tubular housing part 18 which, for example, may enclose or receive an axially movable valve part including an armature 19, a bar-shaped valve needle 20 and an elongated valve-seat support 21. Both housing parts 16 and 18 may be permanently joined to one another by, for example, a circumferential welded seam. The sealing between housing part 18 and valve-seat support 21 may be effected, for example, by a sealing ring 22. Valve-seat support 21 includes, over its entire axial extension, an inner through hole 24 that runs concentrically with respect to the longitudinal valve axis.

With its lower end, which also functions as the downstream termination of entire fuel injector 5, valve-seat support 21 surrounds a disk-shaped valve-seat element 26, fitted into through hole 24, including a valve-seat surface 27 tapering frustoconically downstream. Arranged in through hole 24 is valve needle 20, which has a valve-closure section 28 at its downstream end. This, for example, spherical, partially ball-shaped and conically tapering valve-closure section 28 cooperates with valve-seat surface 27 provided in valve-seat element 26. Downstream of valve-seat surface 27, at least one discharge orifice 32 for the fuel is introduced in valve-seat element 26.

A guide opening 34 provided in valve-seat support 21 at the end facing armature 19 and a disk-shaped guide element 35 arranged upstream of valve-seat element 26 and including a dimensionally accurate guide opening 36 are used for guiding valve needle 20 during its axial movement with armature 19 along the longitudinal valve axis.

The lift of valve needle 20 may be predefined by the installed position of valve-seat element 26. One end position of valve needle 20, when magnetic coil 10 is not energized, may be established by the contact of valve-closure section 28 on valve-seat surface 27 of valve-seat element 26. Another end position of valve needle 20, when magnetic coil 10 is energized, may be established by the contact of armature 19 on the downstream end face of core 11. The surfaces of the components in the stop region may be, for example, chromium-plated.

The electrical contacting of magnetic coil 10, and thus its excitation, may be effected by contact elements 43 ,which, outside of coil form 13, may be provided with a plastic extrusion coat 44. Plastic extrusion coat 44 may also extend over further components (such as, for example, housing parts 16 and 18) of fuel injector 5. Leading out of plastic extrusion coat 44 is electrical connecting cable 6, by which magnetic coil 10 may be energized.

The guide and seat area provided in the end of valve-seat support 21 on the spray-discharge side is formed in its through hole 24 by three axially sequential, disk-shaped, functionally-separate elements. Guide element 35, a swirl element 47 and valve-seat element 26 follow one another in the downstream direction. A compression spring 50 enclosing valve needle 20 secures guide element 35, swirl element 47 and valve-seat element 26 in place in valve-seat support 21. Swirl element 47 may be produced inexpensively, for example, by stamping, wire EDM (electrical discharge machining), laser

cutting, etching or other methods from sheet metal, or by electrodeposition. An inner swirl chamber and a plurality of swirl ducts opening into the swirl chamber are provided in swirl element 47. In this way, before valve seat 27, a swirl component may be impressed on the fuel to be ejected, so that the flow may enter with a swirl into discharge orifice 32, and a fine-swirled and well-atomized spray may be delivered into combustion chamber 3.

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, the problem may occur that the downstream tip of the injector projecting into the combustion chamber may get coked by fuel deposits (that is to say, soot particles in the flame front may deposit on the valve tip). Thus, for injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters (such as, for example, static flow amount, spray dispersal angle, drop size, skeining ability) exists over the service life of the injectors, which may lead to disturbances in the running of the internal combustion engine, up to a failure of the injectors.

According to an exemplary embodiment of the present invention, it is believed that these aforesaid problems may be reduced or eliminated by applying coatings at valve end 8. In this context, different effects on surface 54 of the component to be coated, such as, for example, on valve-seat element 26 made of Cr-steel, may be attained by different coatings. Ultimately, however, these measures are intended to reduce or prevent the coking or formation of covering (soot) on valve end 8, which may have a negative influence on the spray parameters and the valve function. Individual coating possibilities are further described in the following.

Catalytically acting layers may form a first group of coatings. The electrolytically applied layers may provide for

a catalytic conversion (burning) of the deposited soot particles or prevent the deposit of carbon particles. Suitable materials for such a coating to avoid coking may be cobalt, nickel oxides and oxides of alloys of these metals. The noble metals Ru, Rh, Pd, Os, Ir and Pt, and alloys of these metals, among themselves or with other metals, may also exhibit catalytic effectiveness. The desired layers may be produced, for example, by electrochemical or external-currentless metal deposition. In the case of Ni, Co or their alloys, oxide formation in air or an additional oxidation step (using a wet chemical treatment, plasma) may also be used.

Coatings with which wetting properties on corresponding surface 54 may be changed, form a second large group of coatings. These coatings may reduced the surface energy and/or the surface roughness of critical regions at valve end 8. The interfacial energy between surface 54 and the fuel may thereby be increased, which causes the wetting to deteriorate. In this way, the fuel drops at the regions coated according to an exemplary embodiment of the present invention may be able to drip off and may be entrained by the surrounding flow at valve end 8. Permanent wetting of valve end 8 may no longer take place. Such layers may be ceramic coatings, carbon coatings, which may be metal-containing or metal-free, or fluorine-containing coatings. The fluorine-containing coatings may be, for example, heat-resistant PTFE-similar coatings or, in particular, organic ceramic coatings or so-called Ormocer® coatings made of fluorosilicate (FAS). For example, such fluorine-containing coatings may be applied by spraying or dipping. Sapphire coatings may also be applied.

A third group of coatings may be formed, with which a reaction layer may be prevented. Coatings for this third group may be, for example, nitrite layers (TiN, CrN) or oxide layers (tantalum oxide, titanium oxide). Similar to sputtering, for these layers, particles vaporized in a vacuum furnace may be deposited on surfaces 54 to be coated.

The regions to be coated at valve end 8 are, in particular, those that immediately surround the at least one discharge orifice 32 in its outlet area 55, since, a deposit of soot particles in discharge orifice 32 and/or at its immediate boundary edge may lead, in particular, to the disadvantageous influencing of the spray parameters (such as, for example, static flow quantity, spray dispersal angle, drop size, skeining ability) indicated above). Thus, a coating should be applied at the downstream end (outlet area 55) of each individual discharge orifice 32, regardless of on which component of fuel injector 5 discharge orifice 32 may be formed.

Figures 3 and 4 show bottom views of two exemplary embodiments of valve ends 8 coated according to an exemplary embodiment of the present invention. In Figure 3, entire downstream component surface 54 of the component including discharge orifice 32, shown in Figure 3 as valve-seat element 26, is coated. In Figure 4, only an annular partial area of downstream component surface 54 is coated around the at least one discharge orifice 32. The dotted areas show the coated regions. In Figures 3 and 4, outlet areas 55 of discharge orifices 32 lie in the drawing plane (not shown). The coatings may also extend slightly into discharge orifice 32.

In the exemplary embodiments of Figures 3 and 4, valve-seat element 26 is the component of fuel injector 5 that forms downstream end 8 and has discharge orifice 32, so that the coating is applied at downstream end face 54 of valve-seat element 26. However, the application of a coating is not limited to a valve-seat element, but rather other valve components that form downstream valve end 5 and thus project into combustion chamber 3 may also include such a coating. For such components arranged downstream of valve seat 27 (see spray-discharge member 67 in Figure 5), as well, at least the regions immediately at discharge orifices 32 should be coated,

so that the actual spray-discharge area may be protected from coking.

Figure 5 shows an alternative guide and seat region at valve end 8 on the spray-discharge side, to show that an exemplary coating according to the present invention may also be applicable to valve designs that differ structurally. In the exemplary embodiment of Figure 5, a further disk-shaped spray-discharge member 67 is arranged downstream of valve-seat element 26. In this case, spray-discharge member 67 includes discharge orifice 32. Discharge orifice 32 is inclined at an angle with respect to the longitudinal valve axis and terminates downstream in a convexly curved spray-discharge region 66. Spray-discharge member 67 and valve-seat element 26 may be permanently joined to one another by, for example, a welded seam 68 obtained by laser welding, the welding being carried out in an annular circumferential depression 69. In addition, spray-discharge member 67 may be permanently joined to valve-seat support 21 by a welded seam 61. For example, the coating may be applied over entire curved spray-discharge region 66 or directly in a ring shape about outlet area 55 of discharge orifice 32, so that, relative to the longitudinal valve axis, an off-center coating may exist on curved surface 54.

Figure 6 shows a longitudinal cross section through a fuel injector for auto-ignition internal combustion engines, particularly diesel engines, only the part facing the combustion chamber being shown. An enlargement of the end of fuel injector 5 on the combustion chamber side shown in Figure 6 is shown in Figure 7. Valve member 72 is braced against a valve-retaining member 73 by a tension nut 75. Formed in valve member 72 is a bore 84, in which piston-shaped valve needle 20 is arranged, which is axially movable against a closing force. Bore 84 is implemented as a blind-end bore, the closed end of the bore 84 facing combustion chamber 3, forming a valve-seat surface 27 that has a truncated cone shape. Due to a bulge of

the end of valve-seat surface 27 on the combustion chamber side, a blind hole 92 is formed, in whose wall at least one discharge orifice 90 is configured that connects blind hole 92 to combustion chamber 3.

Valve needle 20 is divided into two sections. The first section, which has a larger diameter than the second section, faces away from combustion chamber 3 and is guided in bore 84. The second section has a smaller diameter than the first section, a pressure space 86 being formed between the second section and the wall of bore 84, so that pressure space 86 may be filled with fuel under high pressure by an inlet passage 80 formed in valve-retaining member 73 and valve member 72. Due to the grading of the outside diameter of valve needle 20, a pressure shoulder 82 may be formed, which may be arranged within pressure space 86. The fuel pressure in pressure space 86 produces a force on pressure shoulder 82 whose component operating in the axial direction is directed contrary to the closing force operating on valve needle 20, and thus, given suitable fuel pressure, valve needle 20 may be able to move against the closing force.

Formed on valve needle 20 at the end on the combustion chamber side is a valve-sealing surface 88, forming valve-closure section 28 (not shown in Figure 6 or Figure 7), which cooperates with valve-seat surface 27 so that the at least one discharge orifice 90 is sealed against pressure space 86 by the contact of valve-sealing surface 88 on valve-seat surface 27. Due to the opening lift movement directed inwardly away from combustion chamber 3, valve-sealing surface 88 lifts off of valve-seat surface 27 and connects pressure space 86 to discharge orifice 90.

The catalytically active coating may be applied, for example, over the entire end face of valve member 72 facing combustion chamber 3. Further, only curved outer surface 96 of blind hole wall 93 may be provided, which borders blind hole 92 and in

which the at least one discharge orifice 90 is formed, with a coating. Provision may also be made to continue the coating into discharge orifice 90.

ABSTRACT OF THE DISCLOSURE

A fuel injector, particularly a fuel injector projecting directly into a combustion chamber of an internal combustion engine, including one fuel inlet, an energizable actuating element, by which a valve-closure member is able to be moved, one fixed valve seat, with which the valve-closure member cooperates for opening and closing the valve, and one fuel outlet formed in a downstream valve end, the fuel outlet being formed by at least one discharge orifice arranged downstream of the valve seat. The valve-seat element includes at least one discharge orifice has on its downstream end face, at least in an outlet area of the discharge orifice, a coating to prevent coking in this region.

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FUEL INJECTOR

[Background Information
]

FIELD OF THE INVENTION

The present invention [is based on]relates to a fuel injector[according to the species defined in the main claim].

BACKGROUND INFORMATION

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, particularly with direct injection of gasoline or [the]injection of diesel fuel, [the]a problem [generally occurs]may occur; namely, that the downstream tip of the injectors projecting into the combustion chambers [is]may get coked by fuel deposits[,] (that is[to say], soot particles formed in the flame front may deposit on the valve tip). [That is why, for previously known]Thus, with injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters ([e.g.]such as, for example, static flow amount, spray dispersal angle, drop size, skeining ability) may exist[s] over the[ir] service life of the injectors, which [can]may lead to disturbances in the running of the internal combustion engine[, up to the point of] and a failure of the injectors.

[Summary of the Invention

The]SUMMARY OF THE INVENTION

An exemplary fuel injector [of]according to the present invention [having the characterizing features of the Main Claim has]may have the advantage that [these aforesaid]the negative effects of the coking (soot deposit) on the valve tip projecting into the combustion chamber [are]may be reduced or

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eliminated. The application[, according to the present invention,] of coatings on the downstream valve end, [above all,]especially around the outlet areas of the discharge orifices, may reduce[s] or [prevents the]prevent coking or formation of covering (soot) on the valve end [generally]that may negatively [influencing]influence the spray parameters and the valve function.

[Advantageous further developments and improvements of the fuel injector indicated in the Main Claim are rendered possible by the measures specified in the dependent claims.
]
It [is]may be advantageous to apply layers on the valve end, by which either a catalytic conversion (burning) of the deposits [is]may be effected[,] or the surface energy and/or the surface roughness of the component to be coated [is]may be reduced, a change in the wetting properties thereby being achieved, or the formation of a reaction layer thereby being prevented.

[Brief Description of the Drawing

An exemplary embodiment of]BRIEF DESCRIPTION OF THE DRAWINGS
Figure 1 shows an exemplary fuel injector according to the present invention[is shown in simplified fashion in the Drawing, and is explained in detail in the following description. Figure 1 shows a fuel injector] inserted into a location bore of a cylinder head[;].

Figure 2 shows a longitudinal cross-section of an exemplary fuel injector [in]a[longitudinal section;]ccording to the present invention.

Figure 3 shows[a first exemplary embodiment of] a valve end coated according to [the invention; Figure 4 shows a second]an exemplary embodiment of [a]the present invention.

MARKED UP VERSION OF SUBSTITUTE SPECIFICATION

Figure 4 shows another valve end coated according to an exemplary embodiment of the present invention[;].

Figure 5 shows an alternative guide and seat area on [the]a valve end at the spray-discharge side[;].

Figure 6 shows a longitudinal cross section of [a]an exemplary fuel injector according to the present invention for an auto-ignition internal combustion [engines; and]engine.

Figure 7 shows [the]an end of the fuel injector [according to]of Figure 6 on the combustion chamber side.

[Description of the Exemplary Embodiments
]DETAILED DESCRIPTION

Figure 1 shows a cut-off segment of a cylinder head 1 of an internal combustion engine, particularly a mixture-compressing internal combustion engine with externally supplied ignition[, in a cut-off segment]. Formed in cylinder head 1 is a graded location bore 2 [which]that extends symmetrically along a longitudinal axis 4 up to a combustion chamber 3. A fuel injector 5, according to an exemplary embodiment of the present invention, is inserted into location bore 2 of cylinder head 1. Fuel injector 5 [is]may be used for[the] direct injection of fuel, particularly gasoline, but may also, for example, be used for injection of diesel, as [is]shown [with reference to]in Figures 6 and 7, into combustion chamber 3 of the internal combustion engine. Fuel injector 5 [is preferably able to]may be actuated electromagnetically via an electrical connecting cable 6. The fuel [is]may be supplied to fuel injector 5 [via]by an intake nipple 7. [F]The fuel injector 5 [shown in]of Figure 1 is a[so-called] top-feed injector, in which the fuel is guided in the axial direction from intake nipple 7 through entire injector 5, [it]the fuel being ejected at end 8 on the spray-discharge side, opposite the end on the intake side, into combustion chamber 3.

To protect fuel injector 5 near [to]combustion chamber 3 from overheating, injector 5 [is]may be at least partially surrounded, for example, with a thermal-protection sleeve 9 [likewise]also inserted in location bore 2, [it also being possible to dispense with]although the thermal-protection sleeve may be dispensed with.

Figure 2 shows a cross-section of an exemplary[embodiment of a] fuel injector 5 according to the present invention[in a sectional view]. [It is a]An electromagnetically operable valve[that], which has a tubular, largely hollow-cylindrical core 11 [which]that is at least partially surrounded by a magnetic coil 10[and], is used as the internal pole of a magnetic circuit. [A, f]For example, a graded plastic coil form 13 receives a winding of magnetic coil 10 and, in conjunction with core 11 and a non-magnetic intermediate part 14 partially surrounded by magnetic coil 10, permits a particularly compact and short [design of the]injector in the area of magnetic coil 10. Instead of the electromagnetic actuating element, fuel injector 5 may also be actuated in a piezoelectric or magnetostrictive manner.

Provided in core 11 is a traversing longitudinal opening 15, which extends along a longitudinal valve axis that coincides with the longitudinal axis 4 of the location bore 2 of Figure 1. Core 11 of the magnetic circuit also serves as intake nipple 7. Fixedly joined to core 11 above magnetic coil 10 is an outer metallic ([e.g.]such as, for example, ferritic) housing part 16 which, as an external pole or an outer conductive element, closes the magnetic circuit and completely surrounds magnetic coil 10, at least in the circumferential direction. Provided in the longitudinal opening 15 of core 11 on the intake side is a fuel filter 17 [which]that filters out[those] fuel components [which]that, because of their size, [could]may cause clogging or damage [in]to the injector.

Joined imperviously and fixedly to upper housing part 16 is a lower tubular housing part 18 which, for example, may enclose[s] or receive[s] an axially movable valve part [made of]including an armature 19,[as well as] a bar-shaped valve needle 20 and an elongated valve-seat support 21[, respectively]. Both housing parts 16 and 18 [are]may be permanently joined to one another by, for example, a circumferential welded seam. The sealing between housing part 18 and valve-seat support 21 [is]may be effected, for example, by a sealing ring 22. Valve-seat support 21 [has]includes, over its entire axial extension, an inner through hole 24 [which]that runs concentrically with respect to the longitudinal valve axis.

With its lower end, which [at the same time]also [represents]functions as the downstream termination of entire fuel injector 5, valve-seat support 21 surrounds a disk-shaped valve-seat element 26, fitted into through hole 24, [having]including a valve-seat surface 27 tapering frustoconically downstream. Arranged in through hole 24 is valve needle 20, which has a valve-closure section 28 at its downstream end. This, for example, spherical, partially ball-shaped and conically tapering valve-closure section 28 cooperates[in known manner] with valve-seat surface 27 provided in valve-seat element 26. Downstream of valve-seat surface 27, at least one discharge orifice 32 for the fuel is introduced in valve-seat element 26.

[On the one hand, a]A guide opening 34 provided in valve-seat support 21 at the end facing armature 19[,] and[on the other hand,] a disk-shaped guide element 35 arranged upstream of valve-seat element 26 and [having]including a dimensionally accurate guide opening 36[,] are used for guiding valve needle 20 during its axial movement with armature 19 along the longitudinal valve axis.

The lift of valve needle 20 [is]may be predefined by the installed position of valve-seat element 26. One end position of valve needle 20, when magnetic coil 10 is not energized, [is]may be established by the contact of valve-closure section 28 on valve-seat surface 27 of valve-seat element 26[, while the other]. Another end position of valve needle 20, when magnetic coil 10 is energized, [is yielded]may be established by the contact of armature 19 on the downstream end face of core 11. The surfaces of the components in the [last-named]stop region [are]may be, for example, chromium-plated.

The electrical contacting of magnetic coil 10, and thus its excitation, [is]may be effected [via]by contact elements 43 ,which, outside of coil form 13, [are]may be provided with a plastic extrusion coat 44. Plastic extrusion coat 44 may also extend over further components ([e.g.]such as, for example, housing parts 16 and 18) of fuel injector 5. Leading out of plastic extrusion coat 44 is electrical connecting cable 6, [via]by which magnetic coil 1[is]0 may be energized.

The guide and seat area provided in the end of valve-seat support 21 on the spray-discharge side[,] is formed in its through hole 24 by three axially sequential, disk-shaped, functionally-separate elements. Guide element 35, a swirl element 47 and valve-seat element 26 follow one another in the downstream direction. A compression spring 50 enclosing valve needle 20 secures [the three]guide element[s] 35, swirl element 47 and valve-seat element 26 in place in valve-seat support 21. Swirl element 47 may be produced inexpensively, for example, by stamping, wire EDM (electrical discharge machining), laser cutting, etching or other [known]methods from[a] sheet metal, or by electrodeposition. An inner swirl chamber and a plurality of swirl ducts opening[through] into the swirl chamber are provided in swirl element 47. In this way, before valve seat 27, a swirl component [is]may be impressed on the fuel to be ejected, so that the flow may

enter[s] with a swirl into discharge orifice 32, and a fine-swirled and well-atomized spray [is]may be delivered into combustion chamber 3.

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, the problem [generally]may occur[s] that the downstream tip of the injector projecting into the combustion chamber [is]may get coked by fuel deposits[,] (that is to say, soot particles [formed]in the flame front may deposit on the valve tip). [That is why]Thus, for[previously known] injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters ([e.g.]such as, for example, static flow amount, spray dispersal angle, drop size, skeining ability) exists over the[ir] service life of the injectors, which [can]may lead to disturbances in the running of the internal combustion engine, up to [the point of]a failure of the injectors.

According to an exemplary embodiment of the present invention, it is believed that these aforesaid problems [are]may be reduced or eliminated by applying coatings at valve end 8. In this context, different effects on surface 54 of the component to be coated, [e.g.]such as, for example, on valve-seat element 26 made of Cr-steel, [are]may be attained by different coatings[; u]. Ultimately, however, [all]these measures are [aimed at reducing]intended to reduce or [preventing]prevent the coking or formation of covering (soot) on valve end 8, which may ha[s]ve a[generally] negative influence on the spray parameters and the valve function. Individual coating possibilities are further described[in greater detail] in the following.

Catalytically acting layers [represent]may form a first group of coatings. The electrolytically applied layers may provide for a catalytic conversion (burning) of the deposited soot

particles or prevent the deposit of carbon particles[from the start]. Suitable materials for such a coating to avoid coking [are]may be cobalt[and], nickel oxides and oxides of alloys of these metals[indicated]. The noble metals Ru, Rh, Pd, Os, Ir and Pt, and alloys of these metals, among themselves or with other metals, may also exhibit catalytic effectiveness. The desired layers [are]may be produced, for example, by electrochemical or external-currentless metal deposition. In the case of Ni, Co or their alloys, oxide formation in air or an additional oxidation step (using a wet chemical treatment, plasma) may also be used.

[The c]Coatings with which[the] wetting properties on corresponding surface 54 [are]may be changed, form a second large group of coatings. [Achieved by the]These coatings [in this case is that]may reduced the surface energy and/or the surface roughness of [the]critical regions at valve end 8[is/are reduced]. The interfacial energy between surface 54 and the fuel [is]may thereby be increased, which [means]causes the wetting to deteriorate[s]. In this way, the fuel drops at the regions coated according to an exemplary embodiment of the present invention [are]may be able to drip off and [are]may be entrained by the surrounding flow at valve end 8. Permanent wetting of valve end 8 may no longer take[s] place. [Presenting themselves as s]Such layers [are]may be ceramic coatings, carbon coatings, which may be metal-containing or metal-free, or fluorine-containing coatings. The fluorine-containing coatings [are]may be, for example, heat-resistant PTFE-similar coatings or, in particular, organic ceramic coatings or so-called Ormocer® coatings made of fluorosilicate (FAS). For example, such fluorine-containing coatings [are]may be applied by spraying or dipping. Sapphire coatings [are]may also [conceivable]be applied.

A third group [is formed by the]of coatings may be formed, with which a reaction layer [can]may be prevented. [Among

these are]Coatings for this third group may be, for example, nitrite layers (TiN, CrN) or oxide layers (tantalum oxide, titanium oxide). Similar to sputtering, for these layers, particles vaporized in a vacuum furnace [are]may be deposited on surfaces 54 to be coated.

[
]The regions to be coated at valve end 8 are, in particular, those [which]that immediately surround the at least one discharge orifice 32 in its outlet area 55[. Namely], since, a deposit of soot particles in discharge orifice 32 and/or at its immediate boundary edge may lead[s], in particular, to the disadvantageous influencing of the spray parameters ([e.g.]such as, for example, static flow quantity, spray dispersal angle, drop size, skeining ability) indicated above). Thus[, in any case], a coating should be applied at the downstream end (outlet area 55) of each individual discharge orifice 32, regardless of on which component of fuel injector 5 discharge orifice[s] 32 [are]may be formed.

Figures 3 and 4 show bottom views of two exemplary embodiments of valve ends 8[,] coated according to an exemplary embodiment of the present invention[, i]. In [bottom views which differ in that, in one case]Figure 3, entire downstream component surface 54 of the component [having]including discharge orifice 32, [here]shown in Figure 3 as valve-seat element 26, is coated[(]. In Figure [3), and in the other case]4, only an annular partial area of downstream component surface 54 is coated around the at least one discharge orifice 32[(Figure 4).
]. The dotted areas[are intended to clearly] show the coated regions. In Figures 3 and 4, outlet areas 55 of discharge orifices 32 lie in the drawing plane[. It should be emphasized that t] (not shown). The coatings may also extend slightly into discharge orifice 32.

In the exemplary embodiments [shown]of Figures 3 and 4,[in each case valve- seat] valve-seat element 26 is the component of fuel injector 5 [which]that forms downstream end 8 and has discharge orifice 32, so that the coating is[to be] applied at downstream end face 54 of valve-seat element 26. However, the application of a coating [according to the present invention]is not limited to a valve-seat element, but rather other valve components [which]that form downstream valve end 5 and thus project into combustion chamber 3 may also [have]include such a coating. For such components arranged downstream of valve seat 27 (see spray-discharge member 67 in Figure 5), as well, at least the regions immediately at discharge orifices 32 should be coated, so that the actual spray-discharge area [is]may be protected from coking.

Figure 5 shows an alternative guide and seat region at valve end 8 on the spray-discharge side, [in order]to [elucidate]show that [the assertions with respect to the]an exemplary coating [of]according to the present invention [are]may also be applicable to valve designs [which]that differ structurally. In th[is]e exemplary embodiment of Figure 5, a further disk-shaped spray-discharge member 67 is arranged downstream of valve-seat element 26. In this case, spray-discharge member 67 [has]includes discharge orifice 32. Discharge orifice 32 is inclined at an angle with respect to the longitudinal valve axis[,] and terminates downstream in a convexly curved spray-discharge region 66. Spray-discharge member 67 and valve-seat element 26 [are]may be permanently joined to one another by, for example, a welded seam 68 obtained by laser welding, the welding being carried out in an annular circumferential depression 69. In addition, spray-discharge member 67 [is]may be permanently joined to valve-seat support 21 by a welded seam 61. For example, the coating [is]may be applied[either] over entire curved spray-discharge region 66[,] or directly in a ring shape about outlet area 55 of discharge orifice 32, so that, relative to

the longitudinal valve axis, an off-center coating may exist[s] on[a] curved surface 54.

Figure 6 shows a longitudinal cross section through a fuel injector for auto-ignition internal combustion engines, particularly diesel engines, only the part facing the combustion chamber being shown. An enlargement of the end of fuel injector 5 on the combustion chamber side shown in Figure 6 is shown in Figure 7. [A component constructed as v]Valve member 72 is braced against a valve-retaining member 73 by a tension nut 75. Formed in valve member 72 is a bore 84, in which piston-shaped valve needle 20 is arranged[that], which is axially movable against a closing force. Bore 84 is implemented as a blind-end bore, the closed end of the bore 84 facing combustion chamber 3, forming a valve-seat surface 27 [which essentially]that has a truncated cone shape. Due to a bulge of the end of valve-seat surface 27 on the combustion chamber side, a blind hole 92 is formed, in whose wall at least one discharge orifice 90 is configured [connecting]that connects blind hole 92 to combustion chamber 3.

Valve needle 20 is divided into [a]two sections. The first section, which has a larger diameter than the second section, [facing]faces away from combustion chamber 3[, which has a larger diameter] and is guided in bore 84[, and a]. The second section [having]has a smaller diameter[, between which] than the first section, a pressure space 86 being formed between the second section and the wall of bore 84, [a]so that pressure space 86 [is formed which is able to]may be filled with fuel under high pressure [via]by an inlet passage 80 formed in valve-retaining member 73 and valve member 72. Due to the grading of the outside diameter of valve needle 20, a pressure shoulder 82 [is]may be formed[on it], which [is]may be arranged within pressure space 86. The fuel pressure in pressure space 86 produces a force on pressure shoulder 82 whose component operating in the axial direction is directed

contrary to the closing force operating on valve needle 20, and thus, given suitable fuel pressure, valve needle 20 [is]may be able to move against the closing force.

Formed on valve needle 20 at the end on the combustion chamber side is a valve-sealing surface 88, forming valve-closure section 28 (not shown in Figure 6 or Figure 7), which cooperates with [valve- seat]valve-seat surface 27 [in such a way]so that the at least one discharge orifice 90 is sealed against pressure space 86 by the contact of valve-sealing surface 88 on valve-seat surface 27. Due to the opening lift movement directed inwardly away from combustion chamber 3, valve-sealing surface 88 lifts off of valve-seat surface 27 and connects pressure space 86 to discharge orifice 90.

The catalytically active coating [is]may be applied, for example, over the entire end face of valve member 72 facing combustion chamber 3. [It is also possible to provide]Further, only curved outer surface 96 of blind hole wall 93 may be provided, which borders blind hole 92 and in which the at least one discharge orifice 90 is formed, with a coating. Provision may also be made to continue the coating into discharge orifice 90.

[Abstract]

ABSTRACT OF THE DISCLOSURE

[The present invention relates to a]A fuel injector[(5)], particularly a fuel injector projecting directly into a combustion chamber of an internal combustion engine, [having]including one fuel inlet[(7)],[having] an energizable actuating element[(10],[11, 19)] by which a valve-closure member [(28)]is able to be moved, [having]one fixed valve seat[(27)], with which the valve-closure member[(28)] cooperates for opening and closing the valve, and [having]one fuel outlet formed in a downstream valve end[(8)], the fuel outlet being formed by at least one discharge orifice [(32)]arranged downstream of the valve seat[(27)]. The valve-seat element [(26) having]includes at least one discharge orifice [(32)]has on its downstream end face[(54)], at least in an outlet area[(55)] of the discharge orifice[(32)], a coating [which]to prevent[s] coking in this region.

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~~FUEL INJECTOR~~

Background Information

The present invention is based on a fuel injector according to the species defined in the main claim.

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, particularly with direct injection of gasoline or the injection of diesel fuel, the problem generally occurs that the downstream tip of the injector projecting into the combustion chambers is coked by fuel deposits, that is to say, soot particles formed in the flame front deposit on the valve tip. That is why, for previously known injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters (e.g. static flow amount, spray dispersal angle, drop size, skeining ability) exists over their service life, which can lead to disturbances in the running of the internal combustion engine, up to the point of a failure of the injector.

Summary of the Invention

The fuel injector of the present invention having the characterizing features of the Main Claim has the advantage that these aforesaid negative effects of the coking (soot deposit) on the valve tip projecting into the combustion chamber are reduced or eliminated. The application, according to the present invention, of coatings on the downstream valve end, above all, around the outlet areas of the discharge orifices, reduces or prevents the coking or formation of covering (soot) on

the valve end generally negatively influencing the spray parameters and the valve function.

Advantageous further developments and improvements of the fuel injector indicated in the Main Claim are rendered possible by the measures specified in the dependent claims.

It is advantageous to apply layers on the valve end by which either a catalytic conversion (burning) of the deposits is effected, or the surface energy and/or the surface roughness of the component to be coated is reduced, a change in the wetting properties thereby being achieved, or the formation of a reaction layer thereby being prevented.

Brief Description of the Drawing

An exemplary embodiment of the present invention is shown in simplified fashion in the Drawing, and is explained in detail in the following description. Figure 1 shows a fuel injector inserted into a location bore of a cylinder head; Figure 2 shows a fuel injector in a longitudinal section; Figure 3 shows a first exemplary embodiment of a valve end coated according to the invention; Figure 4 shows a second exemplary embodiment of a valve end coated according to the invention; Figure 5 shows an alternative guide and seat area on the valve end at the spray-discharge side; Figure 6 shows a longitudinal section of a fuel injector for auto-ignition internal combustion engines; and Figure 7 shows the end of the fuel injector according to Figure 6 on the combustion chamber side.

Description of the Exemplary Embodiments

Figure 1 shows a cylinder head 1 of an internal combustion engine, particularly a mixture-compressing internal combustion engine with externally supplied ignition, in a cut-off segment. Formed in cylinder head 1 is a graded location bore 2 which extends symmetrically along a longitudinal axis 4 up to a combustion chamber 3. A fuel injector 5 according to the present invention is inserted into location bore 2 of cylinder head 1. Fuel injector 5 is used for the direct injection of fuel, particularly gasoline, but also, for example, diesel, as is shown with reference to Figures 6 and 7, into combustion chamber 3 of the internal combustion engine. Fuel injector 5 is preferably able to be actuated electromagnetically via an electrical connecting cable 6. The fuel is supplied to fuel injector 5 via an intake nipple 7. Fuel injector 5 shown in Figure 1 is a so-called top-feed injector in which the fuel is guided in the axial direction from intake nipple 7 through entire injector 5, it being ejected at end 8 on the spray-discharge side, opposite the end on the intake side, into combustion chamber 3.

To protect fuel injector 5 near to combustion chamber 3 from overheating, injector 5 is at least partially surrounded, for example, with a thermal-protection sleeve 9 likewise inserted in location bore 2, it also being possible to dispense with the thermal-protection sleeve.

Figure 2 shows an exemplary embodiment of a fuel injector 5 according to the present invention in a sectional view. It is an electromagnetically operable valve that has a tubular, largely hollow-cylindrical core 11 which is at least partially surrounded by a magnetic coil 10 and is used as the internal pole of a magnetic circuit. A, for example, graded plastic coil form 13 receives a winding of magnetic coil 10 and, in conjunction with core 11 and a non-magnetic intermediate part 14 partially surrounded

by magnetic coil 1, permits a particularly compact and short design of the injector in the area of magnetic coil 1. Instead of the electromagnetic actuating element, fuel injector 5 may also be actuated in a piezoelectric or magnetostrictive manner.

Provided in core 11 is a traversing longitudinal opening 15 which extends along a longitudinal valve axis that coincides with longitudinal axis 4 of location bore 2. Core 11 of the magnetic circuit also serves as intake nipple 7. Fixedly joined to core 11 above magnetic coil 1 is an outer metallic (e.g. ferritic) housing part 16 which, as external pole or outer conductive element, closes the magnetic circuit and completely surrounds magnetic coil 1, at least in the circumferential direction. Provided in longitudinal opening 15 of core 11 on the intake side is a fuel filter 17 which filters out those fuel components which, because of their size, could cause clogging or damage in the injector.

Joined imperviously and fixedly to upper housing part 16 is a lower tubular housing part 18 which, for example, encloses or receives an axially movable valve part made of an armature 19, as well as a bar-shaped valve needle 20 and an elongated valve-seat support 21, respectively. Both housing parts 16 and 18 are permanently joined to one another by, for example, a circumferential welded seam. The sealing between housing part 18 and valve-seat support 21 is effected, for example, by a sealing ring 22. Valve-seat support 21 has, over its entire axial extension, an inner through hole 24 which runs concentrically with respect to the longitudinal valve axis.

With its lower end, which at the same time also represents the downstream termination of entire fuel injector 5, valve-seat support 21 surrounds a disk-shaped

valve-seat element 26, fitted into through hole 24, having a valve-seat surface 27 tapering frustoconically downstream. Arranged in through hole 24 is valve needle 20 which has a valve-closure section 28 at its downstream end. This, for example, spherical, partially ball-shaped and conically tapering valve-closure section 28 cooperates in known manner with valve-seat surface 27 provided in valve-seat element 26. Downstream of valve-seat surface 27, at least one discharge orifice 32 for the fuel is introduced in valve-seat element 26.

On the one hand, a guide opening 34 provided in valve-seat support 21 at the end facing armature 19, and on the other hand, a disk-shaped guide element 35 arranged upstream of valve-seat element 26 and having a dimensionally accurate guide opening 36, are used for guiding valve needle 20 during its axial movement with armature 19 along the longitudinal valve axis.

The lift of valve needle 20 is predefined by the installed position of valve-seat element 26. One end position of valve needle 20, when magnetic coil 1 is not energized, is established by the contact of valve-closure section 28 on valve-seat surface 27 of valve-seat element 26, while the other end position of valve needle 20, when magnetic coil 1 is energized, is yielded by the contact of armature 19 on the downstream end face of core 11. The surfaces of the components in the last-named stop region are, for example, chromium-plated.

The electrical contacting of magnetic coil 1, and thus its excitation, is effected via contact elements 43 which, outside of coil form 13, are provided with a plastic extrusion coat 44. Plastic extrusion coat 44 may also extend over further components (e.g. housing parts 16 and 18) of fuel injector 5. Leading out of plastic

extrusion coat 44 is electrical connecting cable 6, via which magnetic coil 1 is energized.

The guide and seat area provided in the end of valve-seat support 21 on the spray-discharge side, is formed in its through hole 24 by three axially sequential, disk-shaped, functionally-separate elements. Guide element 35, a swirl element 47 and valve-seat element 26 follow one another in the downstream direction. A compression spring 50 enclosing valve needle 20 secures the three elements 35, 47 and 26 in place in valve-seat support 21. Swirl element 47 may be produced inexpensively, for example, by stamping, wire EDM, laser cutting, etching or other known methods from a sheet metal, or by electrodeposition. An inner swirl chamber and a plurality of swirl ducts opening through into the swirl chamber are provided in swirl element 47. In this way, before valve seat 27, a swirl component is impressed on the fuel to be ejected, so that the flow enters with a swirl into discharge orifice 32, and a fine-swirled and well-atomized spray is delivered into combustion chamber 3.

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, the problem generally occurs that the downstream tip of the injector projecting into the combustion chamber is coked by fuel deposits, that is to say, soot particles formed in the flame front deposit on the valve tip. That is why, for previously known injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters (e.g. static flow amount, spray dispersal angle, drop size, skeining ability) exists over their service life, which can lead to disturbances in the running of the internal combustion engine, up to the point of a failure of the injector.

According to the invention, these aforesaid problems are reduced or eliminated by applying coatings at valve end 8. In this context, different effects on surface 54 of the component to be coated, e.g. on valve-seat element 26 made of Cr-steel, are attained by different coatings; ultimately, however, all measures are aimed at reducing or preventing the coking or formation of covering (soot) on valve end 8 which has a generally negative influence on the spray parameters and the valve function. Individual coating possibilities are described in greater detail in the following.

Catalytically acting layers represent a first group of coatings. The electrolytically applied layers provide for a catalytic conversion (burning) of the deposited soot particles or prevent the deposit of carbon particles from the start. Suitable materials for such a coating to avoid coking are cobalt and nickel oxides and oxides of alloys of the metals indicated. The noble metals Ru, Rh, Pd, Os, Ir and Pt, and alloys of these metals among themselves or with other metals, also exhibit catalytic effectiveness. The desired layers are produced, for example, by electrochemical or external-currentless metal deposition. In the case of Ni, Co or their alloys, oxide formation in air or an additional oxidation step (using a wet chemical treatment, plasma) may also be used.

The coatings with which the wetting properties on corresponding surface 54 are changed, form a second large group. Achieved by the coatings in this case is that the surface energy and/or the surface roughness of the critical regions at valve end 8 is/are reduced. The interfacial energy between surface 54 and the fuel is thereby increased, which means the wetting deteriorates. In this way, the fuel drops at the regions coated according to the present invention are able to drip off and are entrained by the surrounding flow at valve end 8.

Permanent wetting of valve end 8 no longer takes place. Presenting themselves as such layers are ceramic coatings, carbon coatings which may be metal-containing or metal-free, or fluorine-containing coatings. The fluorine-containing coatings are, for example, heat-resistant PTFE-similar coatings or, in particular, organic ceramic coatings or so-called Ormocer® coatings made of fluorosilicate (FAS). For example, such fluorine-containing coatings are applied by spraying or dipping. Sapphire coatings are also conceivable.

A third group is formed by the coatings with which a reaction layer can be prevented. Among these are, for example, nitrite layers (TiN, CrN) or oxide layers (tantalum oxide, titanium oxide). Similar to sputtering, for these layers, particles vaporized in a vacuum furnace are deposited on surfaces 54 to be coated.

The regions to be coated at valve end 8 are in particular those which immediately surround the at least one discharge orifice 32 in its outlet area 55. Namely, a deposit of soot particles in discharge orifice 32 and/or at its immediate boundary edge leads in particular to the disadvantageous influencing of the spray parameters (e.g. static flow quantity, spray dispersal angle, drop size, skeining ability) indicated above. Thus, in any case, a coating should be applied at the downstream end (outlet area 55) of each individual discharge orifice 32, regardless of on which component of fuel injector 5 discharge orifices 32 are formed.

Figures 3 and 4 show two exemplary embodiments of valve ends 8, coated according to the present invention, in bottom views which differ in that, in one case, entire downstream component surface 54 of the component having discharge orifice 32, here valve-seat element 26, is

coated (Figure 3), and in the other case, only an annular partial area of downstream component surface 54 is coated around the at least one discharge orifice 32 (Figure 4). The dotted areas are intended to clearly show the coated regions. In Figures 3 and 4, outlet areas 55 of discharge orifices 32 lie in the drawing plane. It should be emphasized that the coatings may also extend slightly into discharge orifice 32.

In the exemplary embodiments shown, in each case valve-seat element 26 is the component of fuel injector 5 which forms downstream end 8 and has discharge orifice 32, so that the coating is to be applied at downstream end face 54 of valve-seat element 26. However, the application of a coating according to the present invention is not limited to a valve-seat element, but rather other valve components which form downstream valve end 5 and thus project into combustion chamber 3 may also have such a coating. For such components arranged downstream of valve seat 27 (see spray-discharge member 67 in Figure 5), as well, at least the regions immediately at discharge orifices 32 should be coated, so that the actual spray-discharge area is protected from coking.

Figure 5 shows an alternative guide and seat region at valve end 8 on the spray-discharge side, in order to elucidate that the assertions with respect to the coating of the present invention are also applicable to valve designs which differ structurally. In this exemplary embodiment, a further disk-shaped spray-discharge member 67 is arranged downstream of valve-seat element 26. In this case, spray-discharge member 67 has discharge orifice 32. Discharge orifice 32 is inclined at an angle with respect to the longitudinal valve axis, and terminates downstream in a convexly curved spray-discharge region 66. Spray-discharge member 67 and valve-seat element 26 are permanently joined to one

another by, for example, a welded seam 68 obtained by laser welding, the welding being carried out in an annular circumferential depression 69. In addition, spray-discharge member 67 is permanently joined to valve-seat support 21 by a welded seam 61. For example, the coating is applied either over entire curved spray-discharge region 66, or directly in a ring shape about outlet area 55 of discharge orifice 32, so that relative to the longitudinal valve axis, an off-center coating exists on a curved surface 54.

Figure 6 shows a longitudinal section through a fuel injector for auto-ignition internal combustion engines, particularly diesel engines, only the part facing the combustion chamber being shown. An enlargement of the end of fuel injector 5 on the combustion chamber side shown in Figure 6 is shown in Figure 7. A component constructed as valve member 72 is braced against a valve-retaining member 73 by a tension nut 75. Formed in valve member 72 is a bore 84 in which piston-shaped valve needle 20 is arranged that is axially movable against a closing force. Bore 84 is implemented as a blind-end bore, the closed end facing combustion chamber 3 forming a valve-seat surface 27 which essentially has a truncated cone shape. Due to a bulge of the end of valve-seat surface 27 on the combustion chamber side, a blind hole 92 is formed in whose wall at least one discharge orifice 90 is configured connecting blind hole 92 to combustion chamber 3.

Valve needle 20 is divided into a section, facing away from combustion chamber 3, which has a larger diameter and is guided in bore 84, and a section having a smaller diameter, between which and the wall of bore 84, a pressure space 86 is formed which is able to be filled with fuel under high pressure via an inlet passage 80 formed in valve-retaining member 73 and valve member 72.

Due to the grading of the outside diameter of valve needle 20, a pressure shoulder 82 is formed on it which is arranged within pressure space 86. The fuel pressure in pressure space 86 produces a force on pressure shoulder 82 whose component operating in the axial direction is directed contrary to the closing force operating on valve needle 20, and thus, given suitable fuel pressure, valve needle 20 is able to move against the closing force.

Formed on valve needle 20 at the end on the combustion chamber side is a valve-sealing surface 88, forming valve-closure section 28, which cooperates with valve-seat surface 27 in such a way that the at least one discharge orifice 90 is sealed against pressure space 86 by the contact of valve-sealing surface 88 on valve-seat surface 27. Due to the opening lift movement directed inwardly away from combustion chamber 3, valve-sealing surface 88 lifts off of valve-seat surface 27 and connects pressure space 86 to discharge orifice 90.

The catalytically active coating is applied, for example, over the entire end face of valve member 72 facing combustion chamber 3. It is also possible to provide only curved outer surface 96 of blind hole wall 93, which borders blind hole 92 and in which the at least one discharge orifice 90 is formed, with a coating. Provision may also be made to continue the coating into discharge orifice 90.

What is claimed is:

1. A fuel injector (5), particularly fuel injector (5) projecting directly into a combustion chamber (3) of an internal combustion engine, having one fuel inlet (7), having one movable valve-closure member (28), having one fixed valve seat (27) with which the valve-closure member (28) cooperates for opening and closing the valve, and having one fuel outlet formed in a downstream valve end (8), the fuel outlet being formed by at least one discharge orifice (32, 90) arranged downstream of the valve seat (27), wherein component (26, 67, 72) having the at least one discharge orifice (32, 90) has, at least in outlet area (55) of the discharge orifice (32, 90), a coating around the discharge orifice.

2. The fuel injector as recited in Claim 1, wherein the fuel injector projects into the combustion chamber (3) of an internal combustion engine having externally supplied ignition.

3. The fuel injector as recited in Claim 1, wherein the fuel injector projects into the combustion chamber (3) of an auto-ignition internal combustion engine.

4. The fuel injector as recited in one of the foregoing claims, wherein the coating is provided in a ring shape about the discharge orifice (32, 90) of the downstream surface (54, 96) of the component (26, 67, 72).

5. The fuel injector as recited in one of Claims 1 through 3, wherein the coating is provided over the entire surface on the downstream surface (54, 96) of the component (26, 67, 72).

6. The fuel injector as recited in one of Claims 4 or 5, wherein in addition to coating the surface (54, 96) of

the component (26, 67, 72), the coating also extends into the discharge orifice (32, 90).

7. The fuel injector as recited in one of Claims 1 through 6, wherein the coating is in the form of a catalytically active layer of Co or Ni, or cobalt or nickel oxides, or oxides of Co- or Ni-alloys, or Ru, or Rh, or Pd, or Os, or Ir, or Pt, or alloys of these metals among themselves and/or with other metals.

8. The fuel injector as recited in Claim 7, wherein the layer is able to be produced by electrochemical or external-currentless metal deposition.

9. The fuel injector as recited in one of Claims 1 through 6, wherein the coating is implemented as a metal-containing or metal-free carbon layer.

10. The fuel injector as recited in one of Claims 1 through 6, wherein the coating is implemented as a fluorine-containing layer.

11. The fuel injector as recited in Claim 10, wherein the fluorine-containing layer is a layer of fluorosilicate (FAS).

12. The fuel injector as recited in one of Claims 1 through 6, wherein the coating is implemented as a nitrite layer (TiN, CrN).

13. The fuel injector as recited in one of Claims 1 through 6, wherein the coating is implemented as a tantalum oxide layer or titanium oxide layer.

14. The fuel injector as recited in one of the foregoing claims, wherein the component having the at least one

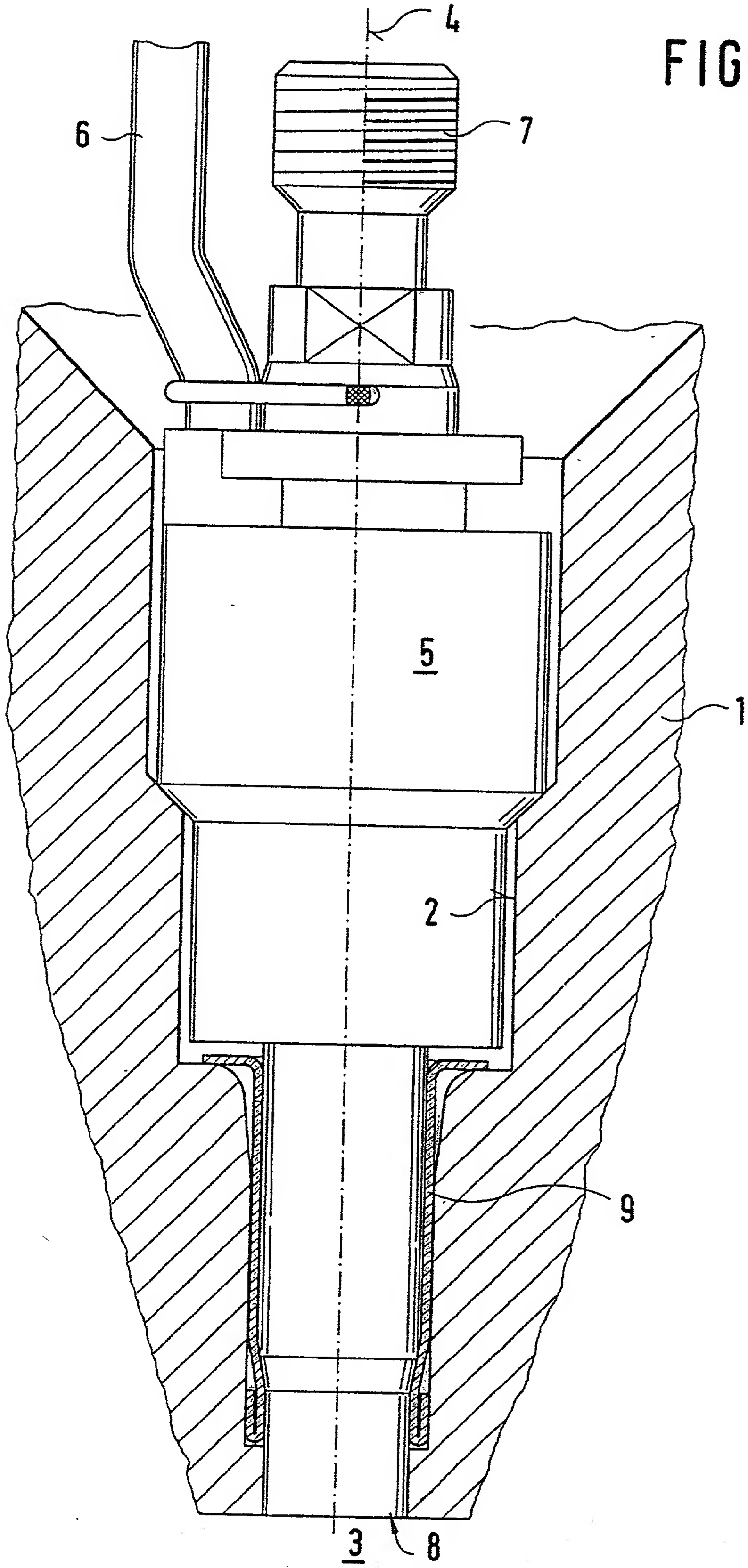
discharge orifice (32, 90) is a valve-seat element (26, 72) also having the valve seat (27).

15. The fuel injector as recited in Claim 14, wherein the valve-seat element (26) has an upstream end face on which the valve-seat surface (27) is formed, and has a downstream end face (54), opposite the upstream end face, on which the coating is applied.

Abstract

The present invention relates to a fuel injector (5), particularly a fuel injector projecting directly into a combustion chamber of an internal combustion engine, having one fuel inlet (7), having an energizable actuating element (10, 11, 19) by which a valve-closure member (28) is able to be moved, having one fixed valve seat (27) with which the valve-closure member (28) cooperates for opening and closing the valve, and having one fuel outlet formed in a downstream valve end (8), the fuel outlet being formed by at least one discharge orifice (32) arranged downstream of the valve seat (27). The valve-seat element (26) having at least one discharge orifice (32) has on its downstream end face (54), at least in outlet area (55) of the discharge orifice (32), a coating which prevents coking in this region.

FIG. 1



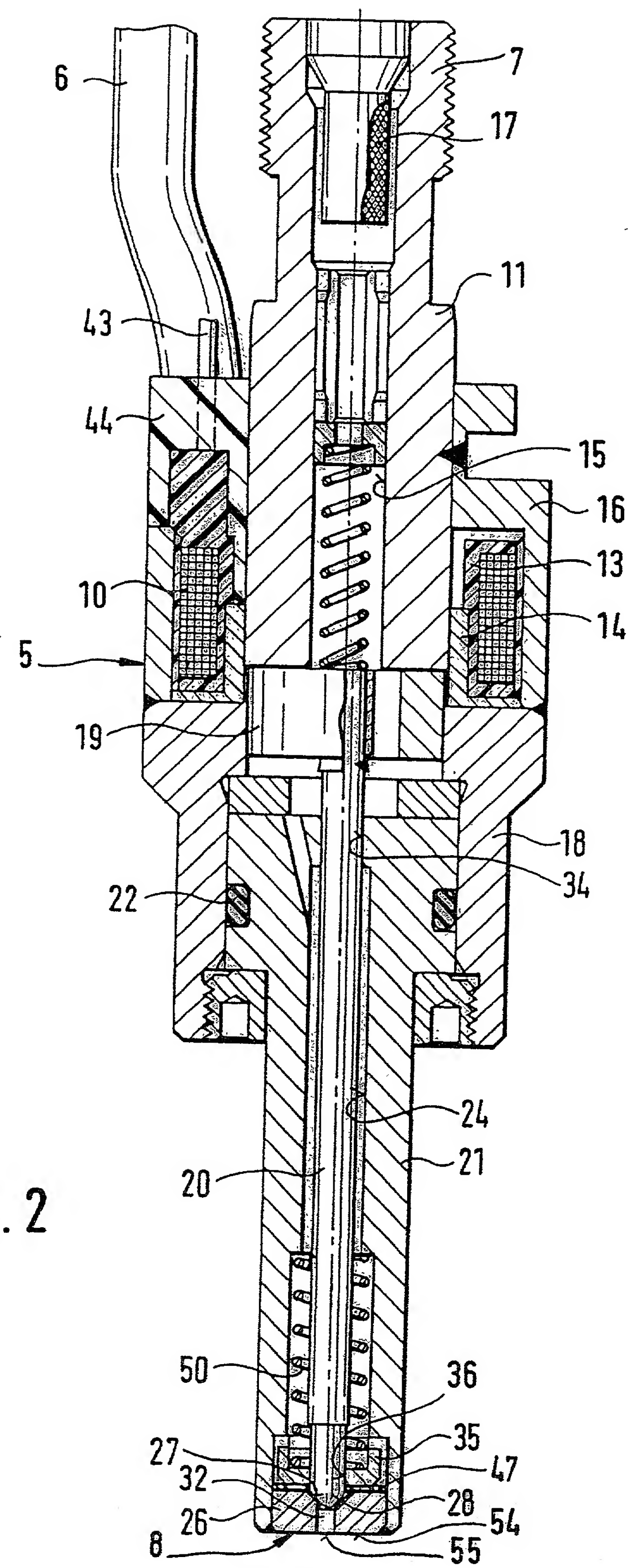


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FIG. 2

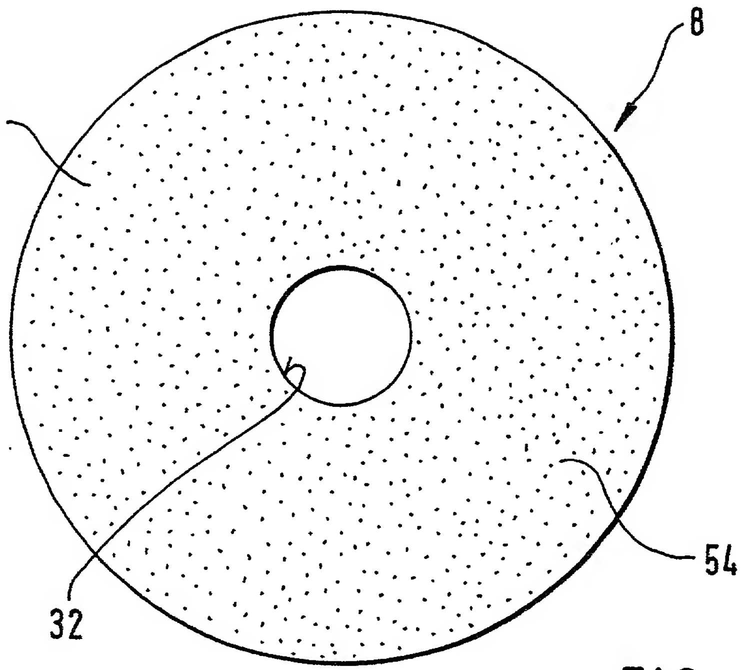


FIG. 3

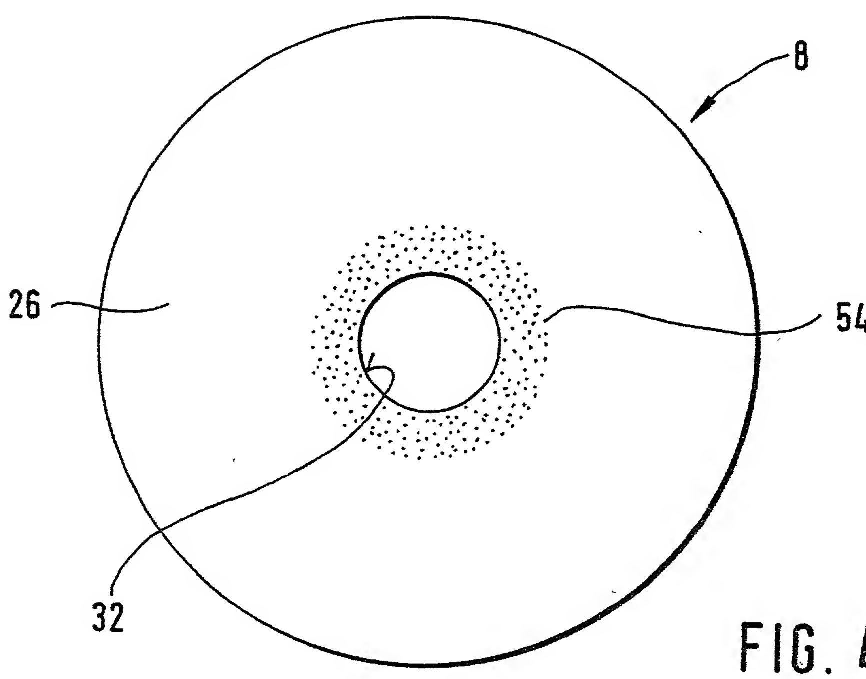
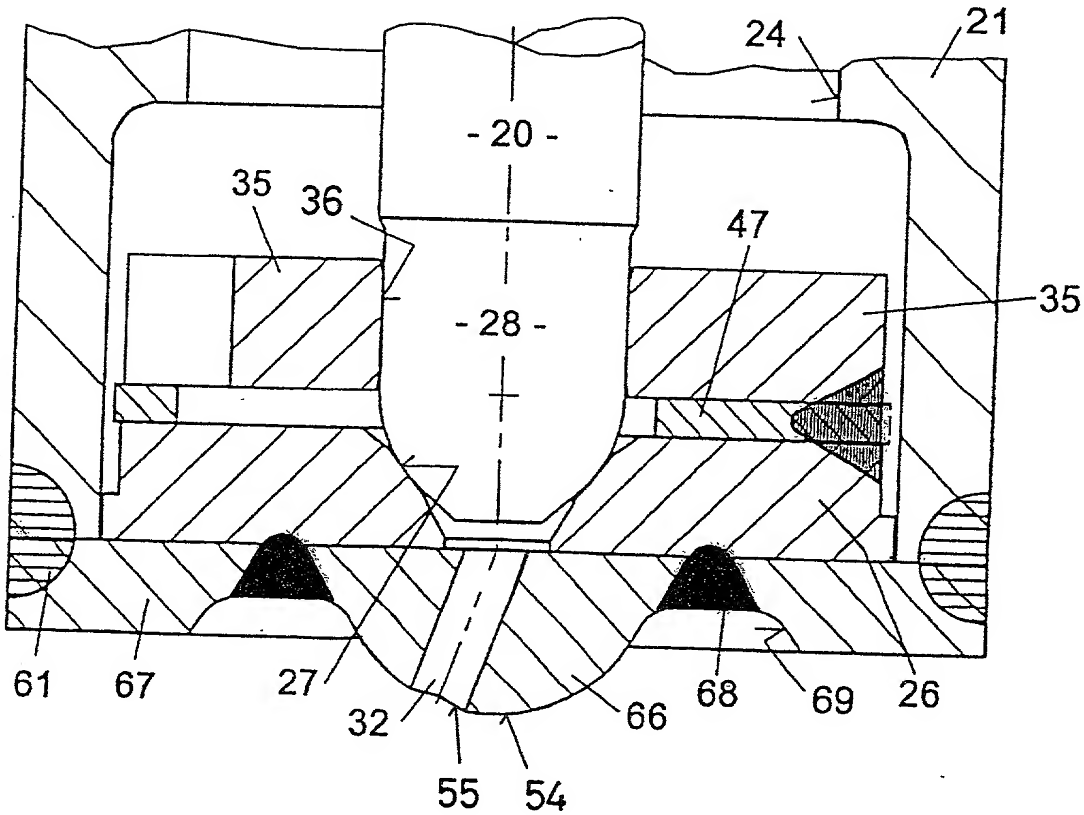


FIG. 4

FIG. 5



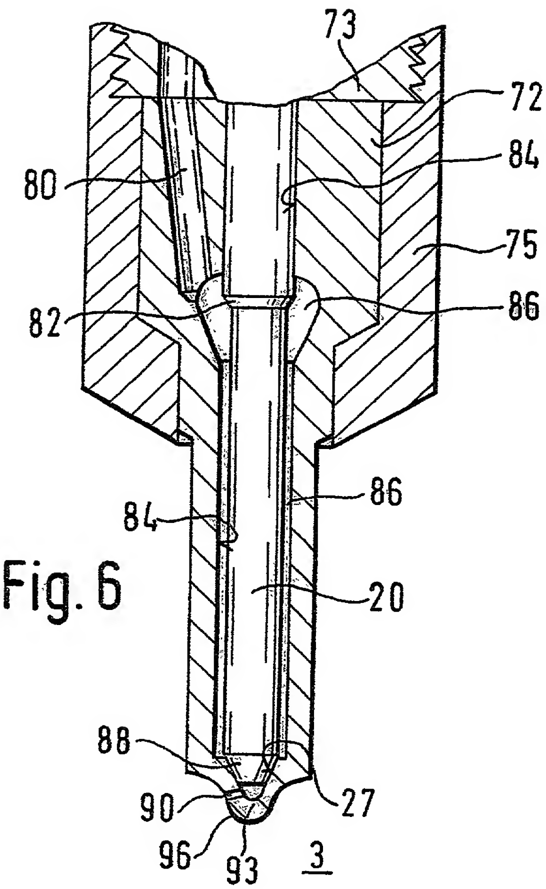


Fig. 6

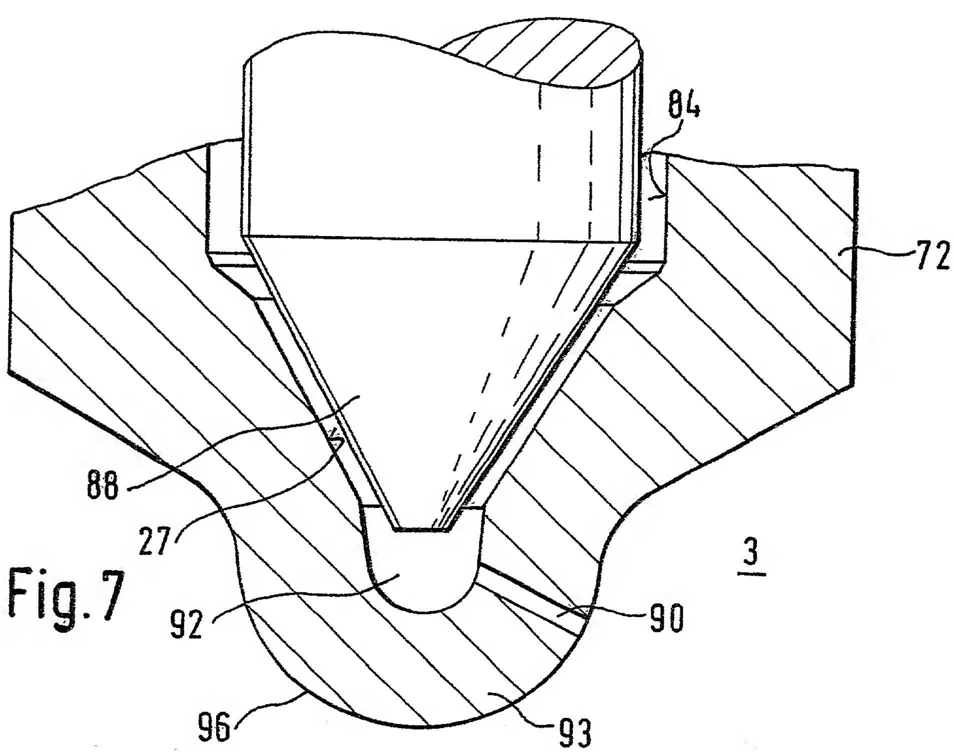


Fig. 7

[10191/2175]

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **FUEL INJECTOR**, the specification of which was filed as International Application **PCT/DE00/02043** on June 30, 2000;

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

Number	Country filed	Day/month/year	Priority Claimed Under 35 USC 119
199 30 637.0	Fed. Rep. of Germany	02 July 1999	Yes
199 51 014.8	Fed. Rep. of Germany	22 October 1999	Yes

And I hereby appoint Richard L. Mayer (Reg. No. 22,490) and Gerard A. Messina (Reg. No. 35,952) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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